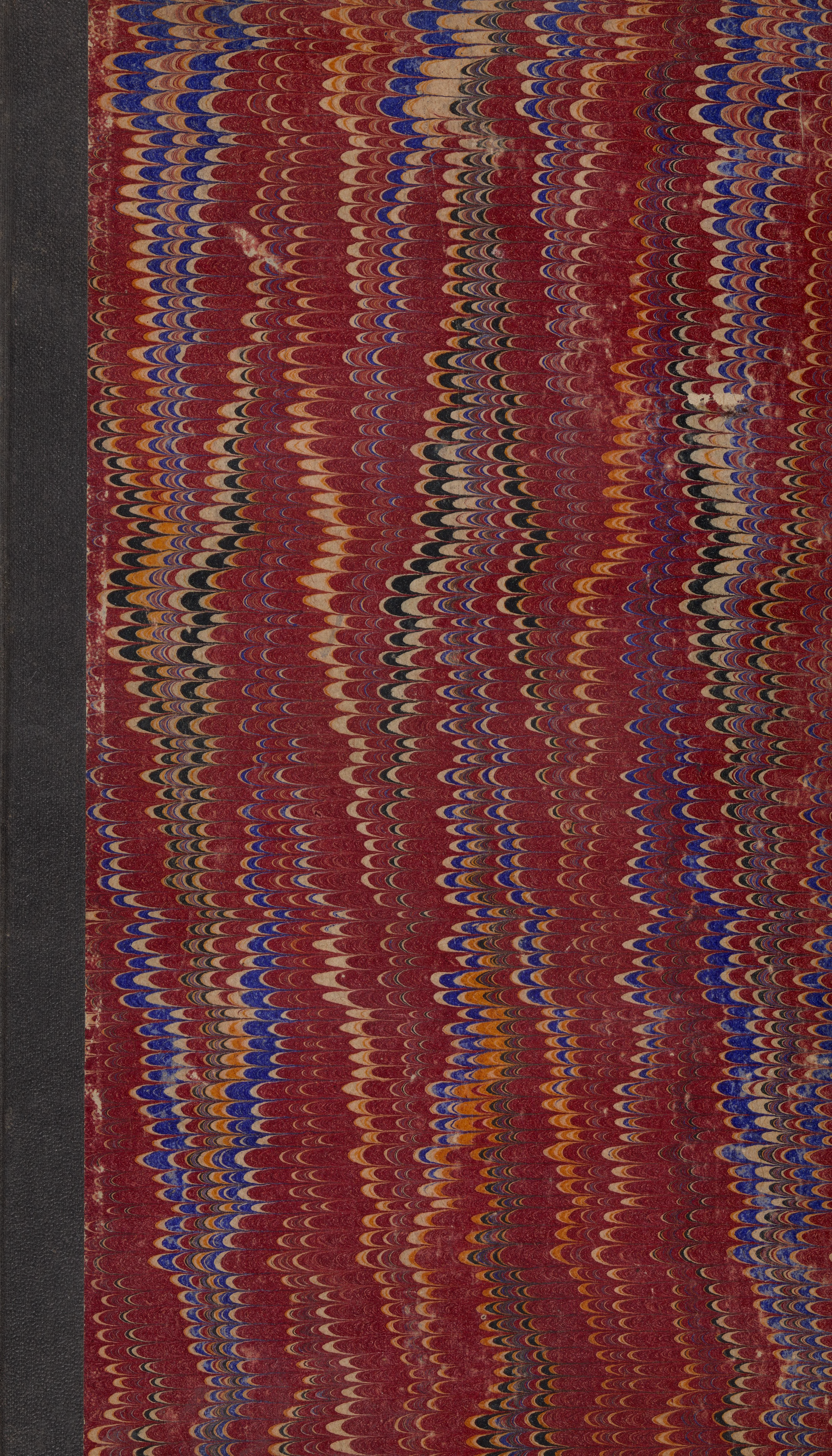
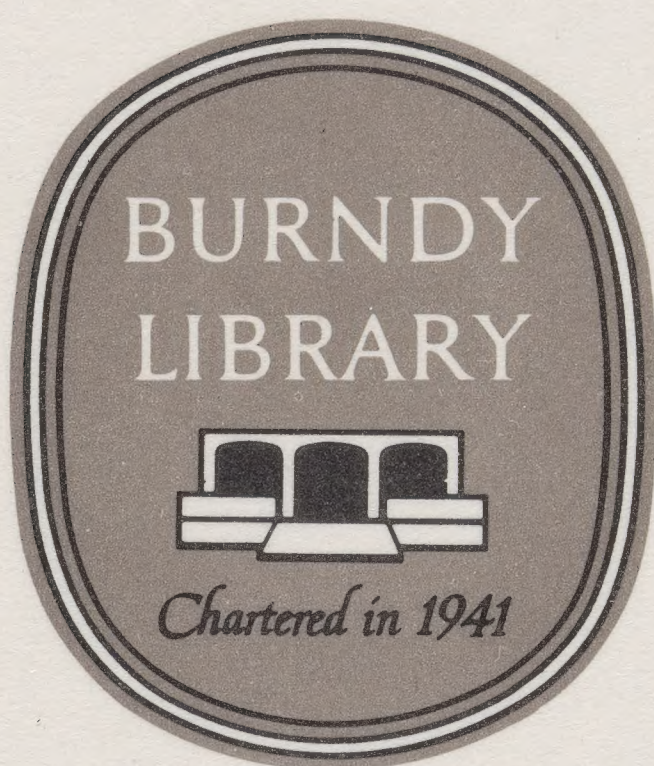






Gift of
BERN DIBNER

Atmosphere Absorption, page 163, vol 28 X

Invisible Heat-Spectrum, page 1 " 31

Wave length " 83 " 32 X

" " " 169 27 X

✓ Absorption " 169 25 X

✓ Absolute Balance 187 21 X

Bolometer - Proc. of Am. Acad. Sci.
of Arts & Sciences (XVI) (1881) X



Professional

Papers of the Senior Service

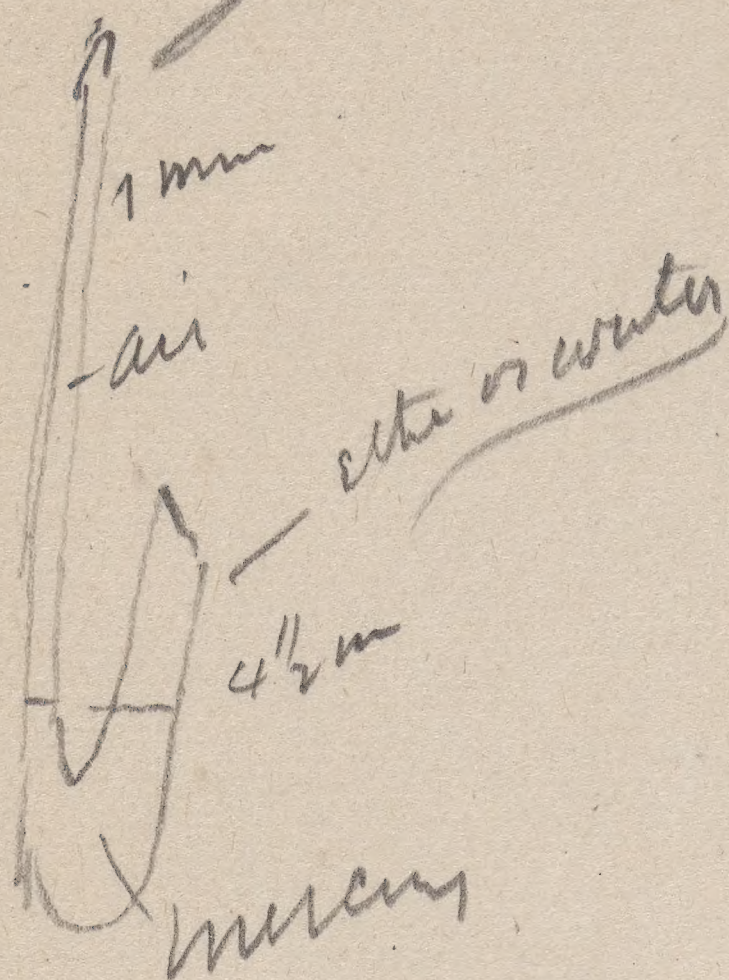
No XL

A report on the work of the

expedition

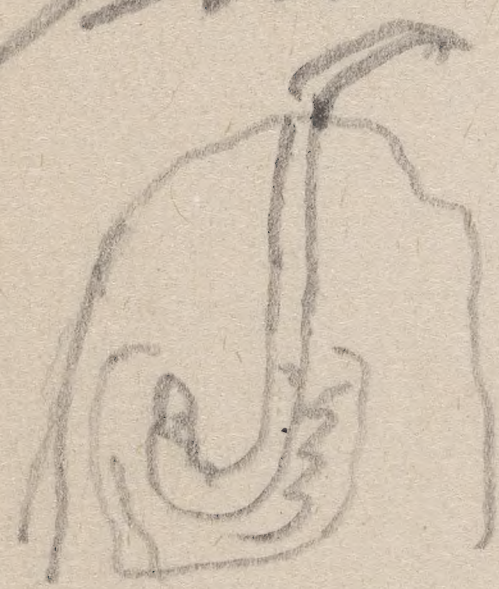
Rosa.

Cagniard de la Tour



Faraday - worked on chlorine,
hydrated chlorine a solid; also
liquefied several gases, nearly all
very liquid, colorless.

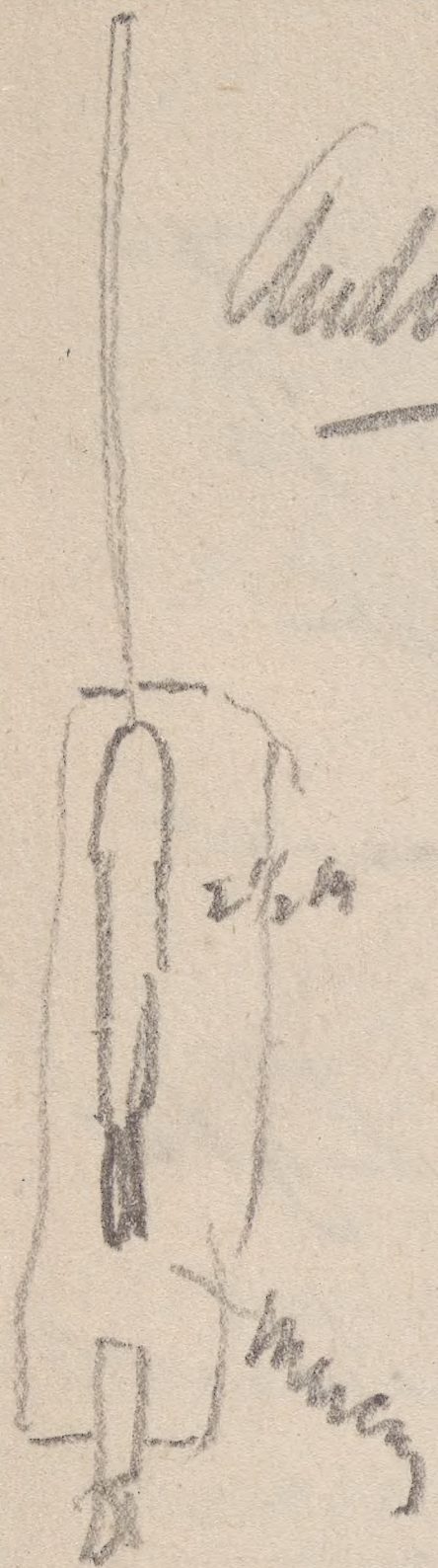
1845 to Royal Society - he used a
condensing pump to produce
pressure, and solid carbonic
acid and ether, ~~from the cold~~
and to measure effect by
putting under air pump.



Chlorine gas, to a clear
liquid.

Hydro bromic acid, to a
colorless liquid, melted at 124
Phosphuretted hydrogen -

Audens 1864



Robert at Geneva began first the re-
called permanent gases Oxygen, Hydrogen
etc

W. Whitney Ex.

Usual to state that extreme violet rays
are most absorbed:— of light rays $\frac{1}{3}$
are absorbed. $\frac{4}{5}$ transmitted— and
red and dark heat rays are almost
wholly absorbed.

✓ The heat... that enters as light,
escapes with difficulty when returned
~~as~~ dark heat in longer waves

This involves that heat of short wave
length is more transmissible than
heat of long wave length

✓ All this rather taken for granted.
Tyndall had proved from experiment
that certain vapors and gases that
form the atmosphere, are almost
impenetrable to heat from sources of
low temp. Wave lengths of these
kinds of heat were not determined,
except by certain assumed formulae.
We are still ignorant on the point

1881 Dreper gives limit of solar heat spectrum at wave length of 0.001 mm .

1883. M. Begunel same limit at 0.0013 mm

largely observed wave length of
nearly 0.003 mm - and finds that
transmissibility of atmosphere
increases up to nearly this point,
when it suddenly ceases. The
larger the wave length the
greater the transmissibility -
he finds that solar constant,
or heat outside of atmosphere,
much greater than hitherto
supposed, and primary
distribution totally different
from what we. Rays found
to be heaped up towards blue
end of spectrum. Color of
sun outside of our atmosphere
would be bluish. - Atmosphere

instead of being transparent, plays
part like that of red or yellow
glass.

We find, as we ascend in
the atmosphere, its transmissibility
(weight for weight) changing, so
that on the whole, quite independ-
ent of its varying density, the
air becomes more and more
transmissible as we ascend.
Also that ratio of transmissibility
at different stations for different
spectral rays, varies. That
transmiss. of blue ray determined
at elevated stations greater than
had expected from observations
at lower stations.

Solar Constant

At Allegheny 2.84 calories

at Whitney 2.6 "

Most probable result from
Comparisons of upper and
lower stations is 3.07 cal.
With upper limit 3.5 and
lower 2.6

Concludes that 3 cal. is
most probable result. that
at Earth's mean distance,
without absorbing atmosphere.
the solar rays would raise
one gramme of water three
degrees C. per minute for
each normally exposed square
cent. m. of surface. Would
melt an ice shell 34.45 meters

deep annually -

Previous observation series
from Posidonia 1.7 col to Verla 2.5

General Conclusions -

(1) Temp. of earth surface not due principally to direct radiation, but to the quality of selective absorption in our atmosphere; without which in the tropics even a vertical sun the temp. of soil would not rise above -20°C - The difference of 215°C is due to this selective absorption.

(2) Generally speaking the radiation which we see enters the air escape within the shortest limits of solar spectrum - The much wave lengths as those belonging to the heat radiation from

the soil, have now entered
our atmosphere from the sun.
But we admit these existences
to solar radiants before absorption.

Use of prismatic spectrum
involves two prominent causes
of error.

(1) Selection absorption (partly
guarded against -)

✓ (2) Acts like a cylindrical lens
concentrating the rays in
lower end of spectrum, and
thus falsifying the true
distribution of heat.

✓ The max. of 'heat' is
found to be not in the
ultra red but in orange,
and the curve of heat

is found to at least approx.
agree with that of light.

Actual solar energy is
nearly at a min when
so called 'actinic' curve
is shown at its max

The elder Dyer pointed
out that the position displaces
the max ordinates of the
red curve towards the lower
or ultra-red end

The measurements with
the grating possess the
great advantage of enabling
us to fix the wave-length
of every ray measured, but

The heat is less than the % of
primaries spectrum -

Observations show heat
in extreme ultra violet rays,
an change of temperature
(not to be observed) in the
Fraunhofer lines. They lead
increased probability that
all the heat can be energy
in any ray can be exhibited
as heat, if there be a proper
medium to receive this energy.
These evidences, as far as it
goes, favor the conception
of our solar energy wh

is interpreted in terms of
heat, or of light, or of chemical
action, according to the
medium we use to observe
it -

Wave lengths

In Sept 1881. observed at Whiting
an unknown cold-band in
dark spectrum - Tried to calculate
its wave length by Cauchy's
formula, lead to an impossible
result - i.e. formula was
faulty -

✓ Every prism gives a different
map of spectrum. - If the
length of the spectra formed
by two different agents, prism
and grating, be made equal,
the red portion of prismatic
spectrum will be narrower than
that of grating - But since
amount of energy must be

really the same in both,
we must, in a graphic
representation of this energy,
increase the height of the
ordinates in the red of the
spectrum so that
the areas shall remain the
same.

✓ Normal or standard
is that of wave length;
and actually that produced
by our most efficient optical
apparatus, the gratings.

✓ But for long waves, the
overlapping spectra of gratings
and prisms make the
too difficult - hence has
to use prism alone & Bolometer

In order to find wave length
from deviation produced by a
prism we have formula

$$h = \frac{\sin \left(\frac{a+d}{2} \right)}{\sin \frac{a}{2}}$$

a = ref. angle of prism.

d = deviation.

h = cos. index of refraction.

This gives relation of deviation
to refractive indices. We
must now find relation bet.
wave-length and ref. indices.

In 1882 used one of Prof.
Rowland's concave gratings.
Apparatus arranged as follows



M concave mirror
focuses on slit S_2

G = grating

S_2 forms spectrum
at S_2 a slit -

T telescope

L lens
E eyepiece

✓ Apparatus adjusted so that
Fraunhofer line D of the 3rd spectrum
of the grating passed slit S_2 .
Then then passed the slit. acc.
to theory of grating -

0.589 (3rd spec. visible)

1.178 (2nd - visible)

1.767 (1st - visible)

Rum P the placed in position
of main division. This separates

the three bands as follows

45°	30	2.60	$41-0$
	0.589	0.172	1.767

Deviation of violet to line

$47^{\circ} 41'$. Then by moving

bolometer till max effect was
found, the position of line 1.467

was found - Deviation (mm)

$45^{\circ} 10'$ Then from

former formula the
refraction index was found.

In this way the deviation
and refraction indices of
known wave lengths were
found.

λ	d	n
1.010 ± 0.0053	$46^{\circ} 12'$	1.3634
$1.2 \pm .0069$	$45-54$	1.5625
$1.658 \pm .0091$	$45-16$	1.5362
$1.767 \pm .0094$	$45-08$	1.5329
$2.090 \pm .0106$	$44-45$	1.5311
$2.356 \pm .0110$	$44-25$	1.5278

Nearly 100 readings were taken for each determination.

from the table we can construct curves showing n as a function of λ or d as a function of λ .

First curve shows errors of the different formulas for the function -

$$n = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4}$$

Cauchy's formula -

By using three known wave lengths
and finding indices, Aris S.D. 14.
of quartz spec. - we may eliminate
 a, b, c and for the prism
formula becomes -

$$n = 1.5593 + \frac{0.006770}{\lambda^2} + \frac{0.0001137}{\lambda^4}$$

This would give least possible
value 1.5593, corresponding to
deviation $45^{\circ} 35'$ but the found
spectrum extends as low as 44° -
Formula can't be relied upon

Biot's,

$$\frac{1}{n^2} = a + b\left(\frac{n^2}{\lambda^2}\right) + c\left(\frac{n^4}{\lambda^4}\right) + k\left(\frac{\lambda^2}{n^2}\right)$$

must mean both, but still
in error.

Table of drill bands in *Leptacris* (9) p. 230

↑

0.815

seen with difficulty. (Brothers & Abney; 2)

.830

(Abney's 8240)

.890

} probably Brothers B.

.905

Very heavy line - Exh. limit of Brothers - commonly also visible -

935-

1.130

Still heavy - Given by Moulton (1.13) Desai's (1.13) commonly & Abney

1.270

Incumbent -

1.360

Group of lines Abney's 4. Last of commonly. { Desai's 1.42

1.805

gt. color band discovered at Whiting. { Moulton 1.42

1.870

Almost endo curve in two at second -

1.985

} small but defined

2.037

These were the last lines
discovered by the volometer -
but the observable spectrum
extends to wave length of
2.70 without notable interruption.
Beyond 2.80 further indications
have been observed - but
they cannot be carried
much farther.

By use of rock salt prism
and lenses, and by arc light
he carried these measurements
much farther.

The following table gives
results of indices of refraction &
wave lengths directly observed.

Ind. of Refr. in
Rock salt μ

Wave lengths from
direct observation
a by eye & b by bolometer

1.5442	$\lambda D_2 = 0.589 \pm 000 (a)$
1.5301	2 $\lambda D_2 = 1.178 \pm .002 (b)$
1.5272	3 $\lambda D_2 = 1.767 \pm 005$
1.5252	4 $\lambda D_2 = 2.3560 \pm 009$
1.5243	5 $\lambda D_2 = 2.9451 \pm 013$
1.5227	6 $\lambda D_2 = 3.5341 \pm 019$
1.5215	7 $\lambda D_2 = 4.1231 \pm 029$
1.5201	8 " = 4.7121 ± 043
1.5186	9 " = 5.3011 ± 065

To show clearly what wave
lengths have been determined
the following table -

Indis. ult. violet	Wave length in μ 0.000145 μ	Photograph -
Violet	0.00081 "	deep red light -
Phosph -	0.00135	Lowest absorbtion band of Bequerel
Bolometer	0.0027	Limit of solar infra- red, wh penetrates atmo-

4.

0.0033 Longest wave measured
by grating & bolometer

0.0075 Approx position of max.
ordinate in heat spectrum
of surface at 1000°.

0.011. Approx pos. of max. ord.
in heat spec. at 0°C.

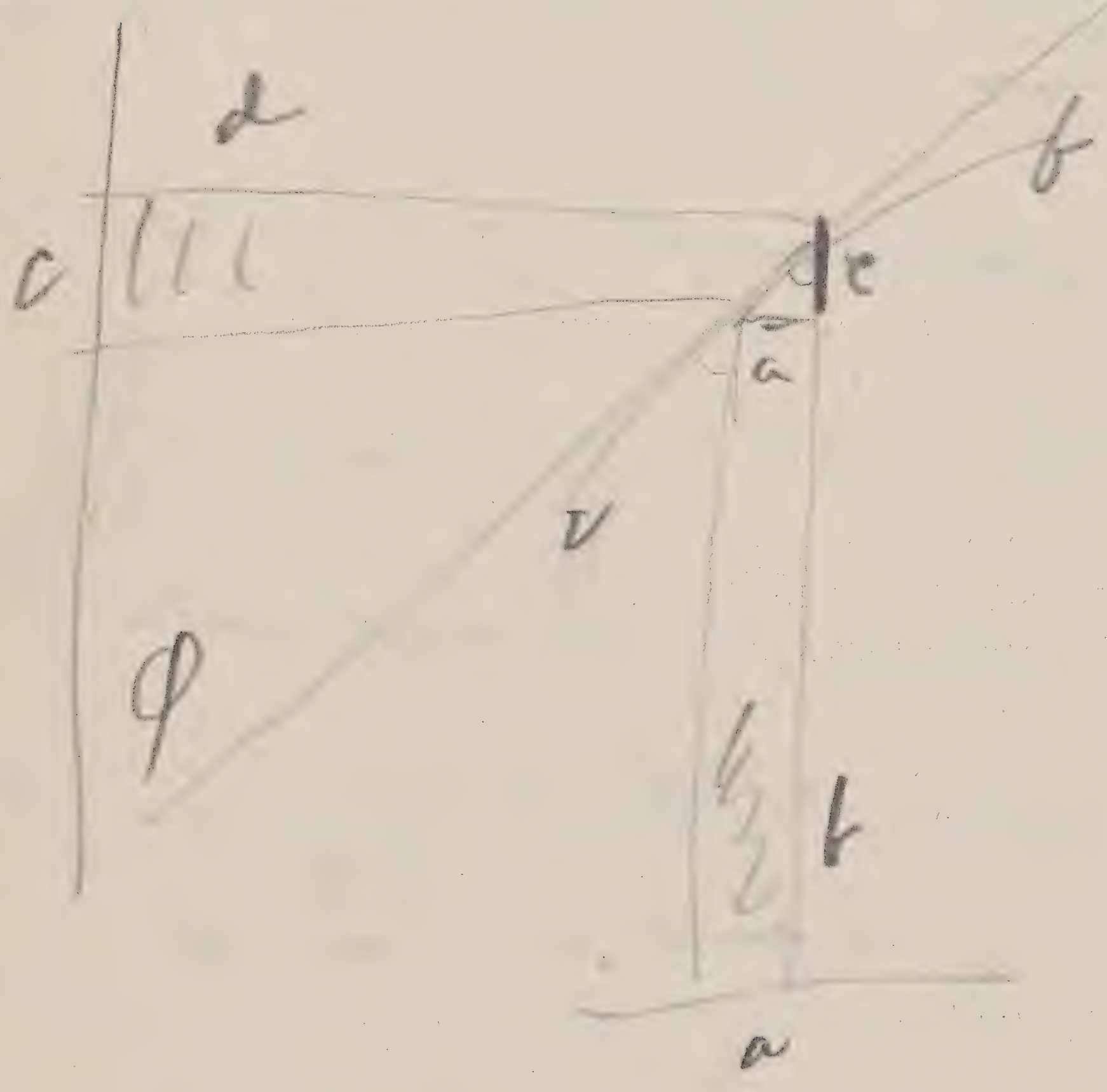
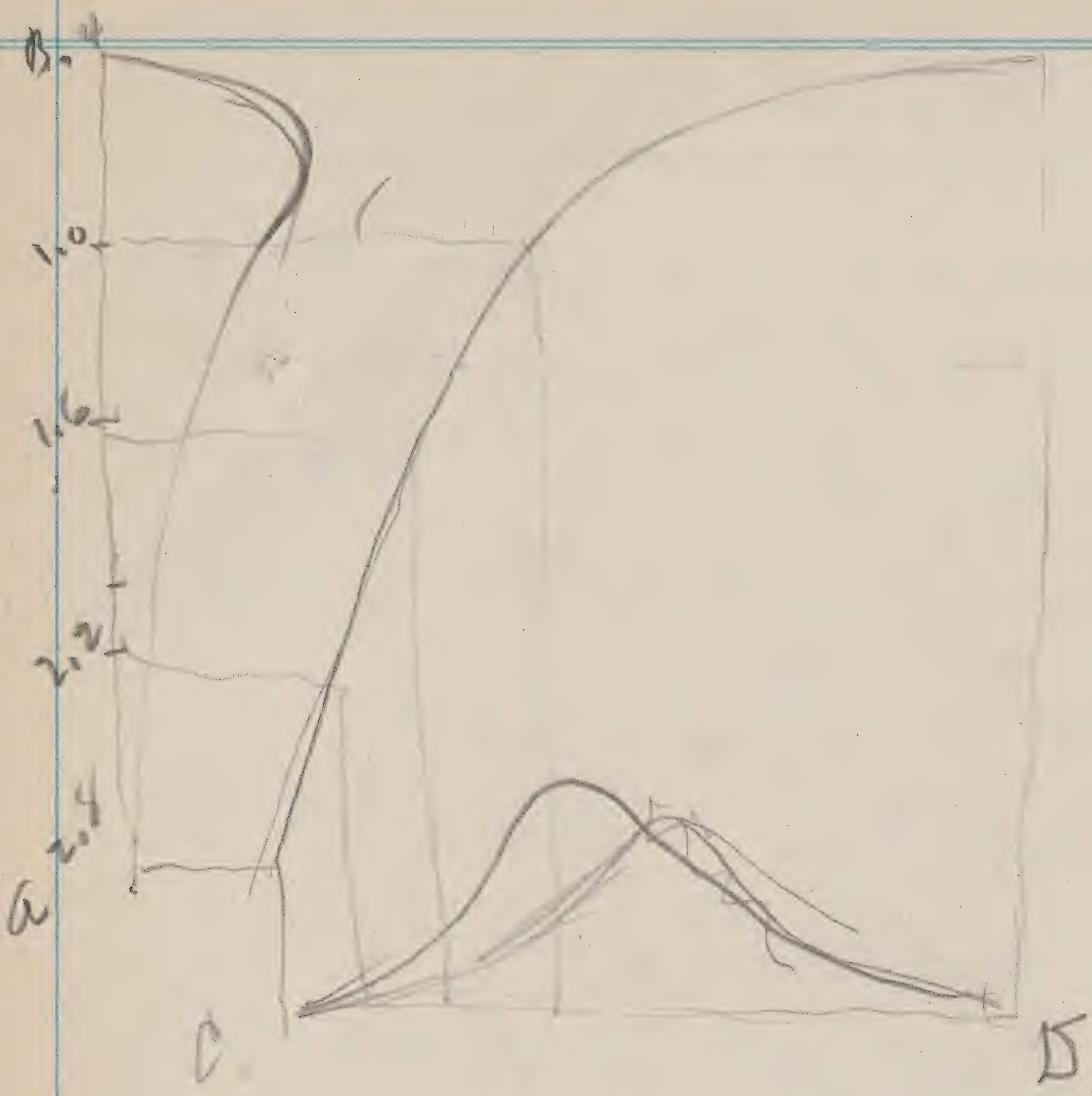
0.030 App. estimate of longest
wave recognizable by the
bolometer in any heat-

14.0 Shortest round wave

Plate (1) vol 32

Distribution of Energy in the normal spectrum -

The curve $d = f(\lambda)$, given Plate IX, enables us to form from our primitive spectrum a map on the wave length scale or normal spectrum - (from $\lambda = 0.344$ to $\lambda = 2.316$) and to draw a curve representing the distribution of energy - If we suppose the curve to represent the amount of energy then the area of the normal curve must = that of the primitive - And again the area between any two wave lengths in the normal must = that in primitive -



Let a be a small wave interval
on prismatic scale, c same on
normal, b & d average heights of
ordinates on these curves - of parts
of curve -

Then we must have -

$$cd = ab$$

$$\therefore b : d :: c : a$$

but from figure

$$\frac{a}{c} = \tan \phi \therefore c : a :: 1 : \tan \phi$$

$$\therefore b : d :: 1 : \tan \phi$$

$$\therefore d = b \tan \phi$$

Hence to find the height of the
normal curve at any point
the corresponding ordinate
of the prismatic curve
must be multiplied by $\tan \phi$

By such a method a table was
constructed from observed

heat a prominent spectrum and
curve drawn —

✓ In 1800 Sir W.^{ts} Herschel in
Phil. Trans. on obscure heat
concludes that heat is an
entity distinct from light.

✓ This view modified into statement
that each ray has 3 qualities —
heat - light, chemical action -
At present time, that same wave
will give either of the three
according to the absorbent

✓ J. W. Draper pointed out
that max of heat did not
always lie in infra-red - (does
in prominent spec) & that in
normal spectrum it would be
in the orange

1210

see previous notes on absorption -

max at
but left of λ

Notes of
absorption

Shows relative
absorption of diff
parts of spectrum

625

max D

325

max C

350

225

100

H

F

D

C

B

A

30

40

50

60

70

80

90

100

Bolometer.

No reliable results obtained with thermopile when grating was used —

Principle of bolometer had been employed by Jamin, Siemens & others. Application new —

Two wires of = length & = section pass to a differential galvanometer so that needle tends to move equally by both. If one wire heated, it becomes poorer conductor, and needle moves by a force proportional either to energy in ray, energy in battery, and to constants of Gal. & rest of circuit

In place of huts wire, heat
a portion of circuit made
of metal. This must be
a thin lamina, non-oxidizable,
should retain its form.

Experiment Dec '79 - Feb 1880 -
found steel, platinum, and
palladium most suitable.

✓ Gold not good because of
minute ruts made by
blows of hammer.

Elementary form -

Roll steel sheets $\frac{1}{500}$ to $\frac{1}{500}$
mm thick 1000 of a mil.
Take two such pieces $\frac{1}{2}$ in long
by $\frac{1}{2}$ in wide, note by note in
an open cylinder - each form
portion of circuit of battery

and galv.

Change of resistance of wire $\frac{4}{10}$ of
170 per degree C. hence a
change of 1°C . causes a diff.
of resistance of $\frac{1}{250}$ of part
expended by $\frac{1}{4}$ whole circuit then
the change cause a different
effect of $\frac{1}{1000}$ on galv.

✓ Again works instantly.

Again (contrary to therm. data)
a strip of $\frac{1}{4}$ area will have
same resistance and any
given % of the resistance
will produce same effect as
before. Unit area 1 sq. mm
set same effect as 1 meter sq.
Practical limit in reducing
size, for current from

battery heats stops and
there is very noticeable in stops
of large resistance and small
area - Action of stops is
nearly independent of its
size -

But if we join ten stops
end to end, we will get
✓ ten times the effect of one

A wide strip will carry a
higher current ^{without heating} - and thus
we have two methods,
low resistance & high current,
or high resistance and
feeble current. We choose
the latter -

Two such systems of shunts
are placed side by side &
enclosed in non-conducting
walls. So that both are
equally warmed or cooled,
& all changes of temperature
in environment, resistance
of coil increased in same
proportion and needle
of gal. unchanged. Except
when one system is heated
by rays —

To practice each system
forms an arm of Wheatstone
bridge — One system

in center of cylinder and
other directed into two
ports on one end side
to change surface radiant
heat into thro' axis of
cylinder.

✓ Current employed $\frac{2}{1}$ of 1000 wts.
wh. heated chips about
 3°C above the surrounding
temp. - Nothing gained by
increasing this as there
are within cylinder sensors
and distributor adjustments.

Both plain steel chips
sensitive from 5 to 100 as
sensitive as for area as
thermopile - Prob. even

of a single observation found
to be very much within one %

As example of delicate
class of measurement - Thon
in heat of morn. Nov. 12 1880
with equatorial of observation.
using 13 in achromatic lens and
other smaller ones. Great many
precautions used. ✓

Bal. cover open. Exposed at all
times to sky and lens radiation -
Lunar image brought in by
moving telescope -

Actual deflection (hnt)

West limb
entire field

{ 3.3
2.8
5.3
5.6
4.4
3.6
7.0

East limb
entire field

{ 6.2
3.9
3.0
3.0

Balance covered except
during exposure. wire kept
in pos. 4 clock.

19
24
23
41
27
37

Mean deflection = 41.6 ± 2.4

Prob. error of single obs. = 9.9

✓ These given as means of
judging the capacity of bolometer
to measure forms of radiant
heat hitherto supposed beyond
reach: 1 by an the first
anthermic measures of the
lunar rays wh. have passed
through the glass lens - to
a refracting telescope.

Lamp. blocked stops gave no indication
of cold when warm heat -
but its deposition on glass conducted
away too much heat.

Stop catches up and parts
with the heat in a fraction
of a second. This a great
advantage over thermopiles -

Sensitive compared with
thermopiles, A, B, C, most delicate
thermopile - S strip of iron -

	Area	Deflection	Sensitivity
A	240 sq. m	211	.9
B	34	125	3.7
C	10	147	14.7
S	1	204	204.0

If we desire to increase
the resistance with same area use
narrow strips and be

Finite instrument

strips are $\frac{1}{500}$ mm. thick,

1 mm wide, 10 mm long-

bent at each end. Each

strips are arm of a Wheatstone
bridge

$\frac{1}{10000}$ of $^{\circ}\text{C}$. produces a

measurable deflection

$\frac{1}{100000}$ $^{\circ}\text{C}$ can be noted.

Exposes about $\frac{1}{2}$ sq. cent. of
surface to radiant energy.

The bolometer with a strip $\frac{1}{500}$ mm
wide can be set by the
invariable heat alone to
within $10''$ of mc .

Used also a specially constructed
galvanometer

A deflection of 1 mm corresponds
to a change of centigrade scale in
the volumetric charts of less
than $\frac{1}{10000}$ of a degree C., and
 $\frac{1}{10}$ of this can be shown

Plate (II) vol (32)

~~Distribution~~
~~Structure of Spectra~~ & Distribution

As with grating you get two overlapping spectra: one with twice wave length of other. allowance must be made.

As all evidence of heat radiation dies out at $\lambda = 0.3 \mu$ in ultra violet, we can measure in 1st spectrum directly, all waves shorter than 0.6μ . And by making allowance for heat in second spectrum of rays $\lambda \leq 0.5 \mu$ we can directly measure in 1st spectrum to $\lambda = 1.0 \mu$ -

(Zero point of Bolometer is in wave length)
Allowance also made for the absorption of specular metal & silver.

Wave lengths derived from measurement angles by formula -

$$n \lambda = \sin i + \sin r -$$

n = order of spectrum

a = space bet. lines of gratings

λ = wave length, i & r angles

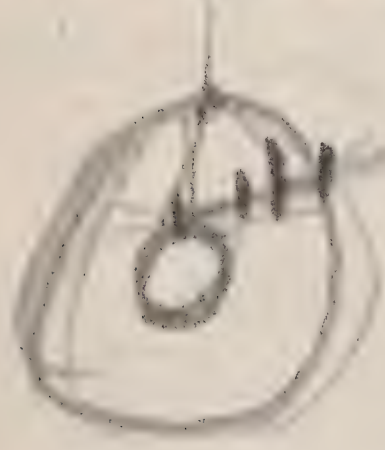
✓ Found that energy in invis. part
down to $\lambda = 1.0 \mu$. must less than
in visible. But also found
that curve of heat extended even -
below this: even detection heat
as low as $\lambda = 3.0 \mu$.

We receive all solar
radiations through an absorbing
atmosphere. To determine the
rate of selective absorption for
each separate ray or wave length.

While solar radiation is
itself sensibly constant, the
radiations actually trans-
mitted by atmosphere vary
from minute to minute even
with a perfectly clear sky.
(Shown by Bolometer)

Absorption

Two sets of measures taken
 throughout the spectrum daily.
 One when rays have been little
 absorbed (noon) and the other when
 greatly absorbed (morning or evening).
 When they pass thro' little atmosphere
 or deep atmosphere



The mass of air
 through wh. the rays pass
 is calculated from the zenith
 distance, and from actual
 barometric pressure. And the
 coeff. of transmission found for
 one atmosp. at sea level (760 mm
 mercury pressure) will serve in zenith.
 This found to vary greatly for
 each ray.

$\lambda = 0.375$ (ultra violet)	61%	absorb.	39 trans.
$\lambda = 0.600$ (orange)	36	"	64 "
$\lambda = 1.004$ (infra-red)	20	"	80 "

Total mass of air

Out of 29 days of obs. only 10 could be used owing to changes in sky

As an example of mode of obs - Jun 22 1882 -

	High Sun		Low Sun -	
03. d.	time	Bar	03 d	time
			Bar	
17° 10'	0 ^h 15 ^m	7.39	79° 8'	6 ^h 25 ^m
			Bar	Bar

The air mass calculated by formula

$M = \frac{0.0174 \text{ Tabular Refract.}}{\cos. \text{ app. alt.}}$ was at

norm 1.047 times that overhead.

$n = 1.047 \times 7.39 = 7.74 \text{ decimeters} = M_1 \beta_1$

Low Sun = 38.27 " $M_2 \beta_2$

Gal. deflection -

44° 30' exten infrared

17^{d.}

Evening

11^{d.}

50 . violet

4.5

0.39

(ndry) The difference in air masses

(norm & even) $38.27 - 7.74 = 30.53 \text{ dm}$

by its absorption produced a

difference of deflection $17 - 11 = 6$

Then by the formula.

$$t = (m_2 \beta_2 - m_1 \beta_1) \sqrt{\frac{d_2}{d_1}} = .986$$

that is a mass of air capable of supporting 1 dec. of mercury transmits 98.6% of the energy of this particular ray. This quantity t , is called the coeff. of transmission of this ray.

But we want the amount transmitted by 7.74 such layers (of 1 dec each) for the sun at noon. This is

$$.986^{7.74} = .895 \text{ or only}$$

89.5% of the original heat of the ray. double δ E. reached us at noon. And this produced a deflection of 17. '.

$$\delta = \frac{17}{.895} = 19. \text{ The}$$

deflection wh. would have been

produced on our instrument
 by the ray outside of our atmosphere

In same way amt of
 violet radiation transmitted at
 noon was 53.8% (Less than
 that for infra red). and its
 Energy outside of atmosphere

$$\frac{455}{538} = 8.4$$

Similar reductions were made
 for the other wave-lengths on that
 Result.

Deviation.	ϵ	Σ
59° 00	1.8	Computed
58	8.4	Energy outside
49 30	—	
49	18.9	to atmosphere
48 ~~30~~	58.8	
47.30	84.7	Expressed in
46. ~~45~~	173.7	
46 12	233.8	Gal. deflections
45 33	198.3	
45 38	136.2	
44 30	19.0	

The transmissibility of the atmosphere
is found to be greatest for
the infra-red rays.

From these and other results
the curves shown in plate 1 page 179 & 20
are drawn - showing (i) the heat
actually observed to $\propto \cos^2 \theta$, for
high sun - (ii) for low sun. And
proportional to heat received
from sun when it shows through
double the air mass of high sun.
(iii) Same outside of atmosphere -
distribution of heat energy before
absorption. These curves show
that proportionally much more of
short rays are absorbed.

Knowing the value in calories
corresponding to the middle
curve we readily obtain
the absolute heat before absorption
(color constant).

$$\frac{\text{Area of outside curve}}{\text{" " Height "}} = \frac{73.66}{46.96} = 1.569$$

allowance being made for
uncharted (hatched) area below $\delta = 1.0$.
Mean of observations at Allshung
was 1.81 calories = area of
height curve.

$$\therefore 1.81 \times 1.569 = 2.84 \text{ calories} =$$

approx value of color constant.
(see color constant notes)

We see from these results that
the max. energy of a hush sun
at Earth's surface is near the
yellow - does not differ much
from that of light.

We see how great is the
absorption of violet rays and
that light rays have been
absorbed much more than
dark heat rays.

7.



Lammont curve

Helicoverpa abstrahens

Historical statements.

1870. Sir Wm. Herschel showed that
but extended below visible - $\frac{1}{2}$ luminous
 $\frac{1}{2}$ dark.

1842 J. W. Peffer observed 3 wide
bands in the infra red region
R. S. & T. states that he thought but that
part of spec. is in yellow.

1846. Foucault & Fizeau same lines. ✓

1871. Lamanby gave a drawing
showing that gaps in infra red.
States however that these infra red
lines are absorbed.

1879. Moulton 4 bands at
.85 .94 1.23 1.58.

Abney in 1880 gave 4 maps

Observed at Whiting a cold band -
(see note on lower lengths) (most of
them can come in here)

51 days of observation -

The totemato shows the cold
is the outside from. Lines
but they have not been mapped.
Each portion of curve observed
from 3 to 10 hours -

The extent of region newly
mapped is considerably larger
on the ground scale, than the
whole of that previously known.

✓ All the energy in the ultra-
violet part is extremely
insignificant.

be see what an enormous
region the infra-red really
is. Nearly a hundred times
as great as ultra-violet.

1st More energy is above the
red and is placed ^{red} ~~at~~ the yellow
Venus on clear day from 0.55 μ to
0.65 μ with low sun.

2^d By comparing ordinates
of high and low sun in
different parts of the spectrum,
we see how they grow
unequally, indicating an
enormous system of absorption
increasing towards the ultra-violet.

and disappears towards
the infra-red and these
observations give the amount of
the absorption. The absorption
in the whole grows less and
less as we go down below
the red to a λ near
 $\lambda = 2.8 \mu$. But very great
local absorption takes place
in the lower red spectrum.
Observations point out new
regions of such local
absorption.

The ratio of luminous to dark
heat has been changed by
selective absorption. This
ratio can be found from the
two areas of our curve.

The ratio of convertible to the whole
is 0.632 - above level - without
the absorber, the ratio of lumin. to
dark becomes much greater -

The relatively small
amount of energy, corresponding
to great wave length in the
infra red, is due not so
much to absorption, as to
the fact that there is

but little energy there -

The relatively great amount
of energy in the luminous
part of the spectrum exists
there, not on account of
feeble absorption, but in
spite of a strong absorption.

Probably the solar spectrum
before absorption (thought weak)
extends very much farther
into the infra-red than
our charts indicate.

To know absolute brightness of
sun or star must know
absorption of atmosphere. The
unit of absorption is generally
given at sea level as about
20% (Seidel 21, Pulchinel
exford 21, Müller 17, Smith
18 & 24) Emission in heat
series 21.

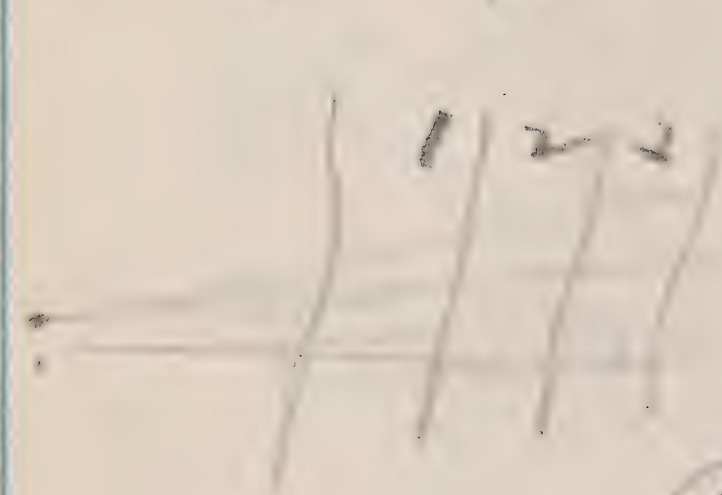
Langley arrives at an
entirely diff. result, makes
it over 40%—

The error of this investigation
was due to formula, which
always gives an error
going one way —

Simply lead by theorems &
experimental observation to
conclusion that ^{laws of} solar heat
heat ^{is} absorbed & almost all
very complex. and that
simple rule used by Herschel
and Pouillet is erroneous.

The assumption originally
made by Bouguer & followers
Herschel etc. was this - Let
beam of light enter dark
room, partly absorbed by reflection
etc say $\frac{1}{2}$ as bright as when
entered - Now let this beam
cross another room, and
it will be diminished in

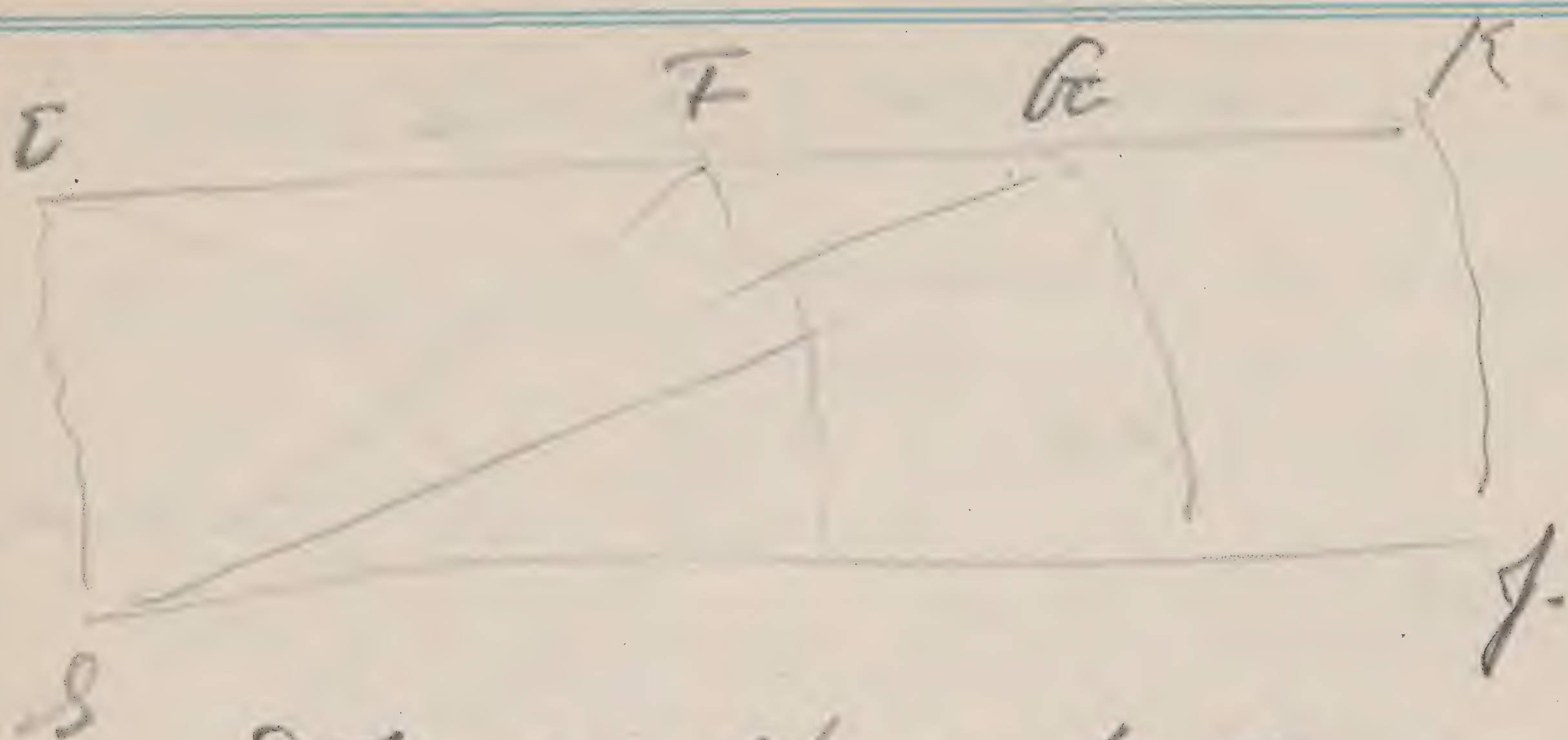
same proportions, and that
 that transmission is same
 kind of light but diminished
 to proportion $\frac{1}{2} \times \frac{1}{2}$ etc -



Boussier -

Let a be source of
 radiant heat or light.

(coeff of transmission) In passing
 first layer a is reduced to $p \cdot a$
 for second layer $p \cdot p \cdot a = p^2 a$
 etc. So that if original and
 of range by a , after passing
 through n it also it will
 be $a p^n$



SJ = earth's surface

EJ = upper surface of stars

$SF = 2 \text{ l.E.}$, $GL = 3 \text{ l.E.}$ etc.

Original heat of sun = a , becomes

when passing through EJ . (in 3 units)
According to the formula

ρa , when sun is $75 = a \rho^2$ etc.

$5a = a \rho^3$ etc. in wh. a & ρ

are unknown.

But by actually drawing
units of heat that reach us
along FS and GS we have

say $a \rho^2 = m$, $a \rho^3 = n$

here can find Q & p .

General formula

$$Qp^{\epsilon} = t.$$

t = obs. values of m & n . ϵ , n^o of observations.

For the formula the fundamental assumption is that p is constant. This largely finds to be true.

The solar energy absorbed is regarded in whole as 'heat,' or 'chemical action' or in part as light. is the sum of an infinite number of radiations which may easily be influenced in an infinite diversity of ways by the atmosphere.

Larger particles (dust etc) reflect
rather than diffuse the rays
and treat all rays alike.
Smaller & smaller particles
whether of dust or mist, act
more and more selectively.
acting more on one end
of spectrum than on other.
The actual molecule acts ~~as~~ ^{on}
on only one ray - The
effect of larger dust particles
is to produce a general
and almost indifferent
absorption. - The effect
of molecular absorption
is to fill the

Spectrum with the evidence
of selective absorption.

Dark lattice lines - taking
out some kind of light
and heat and not other,
so that after absorption what
remains is not only less
in amount, but different in

kind

Pouillet's formula $A_p = t$ is
an assumption that the
same proportion will be
absorbed by one substance as
by another -

Melloni observed } experiment
in his laboratory

that both proportions are
not absorbed by both states

One of reasons why this
was not recognized in
the application to determining
Soln Limit. on a amount of
absorption was the impossibility
of measuring anything but
homogeneous rays

By reflecting the
selected absorption results
are obtained that are
always too small -

He shows that the general
coef. of transmission in the
exponential formula

- (1) is never a constant,
- (2) always too large -
- (3) always larger & larger as
we approach the horizon -
- (4) Hence original light as
lost always too small

To show this. Let original
radiation be composed of
two parts A & B, & coeff's
of transmission respectively
a, b. (Assume each of these two
portions homogeneous)

Then we have results

Orig rad.	Retn	Rad received after 1 str.	what	2
a	a	Aa	Aa ²	Aa ²
B	b	Bb	Bb ²	Bb ²

$$A+B \quad \quad \quad Aa+Bb \quad \quad \quad Aa^2+Bb^2$$

$$\quad \quad \quad = m \quad \quad \quad n = p.$$

The sum

$$\frac{Aa+Bb}{a+B} < \frac{Aa^2+Bb^2}{Aa+Bb} \quad \text{etc}$$

$$\& \quad \frac{Aa^2+Bb^2}{Aa+Bb} < \left(\frac{Aa^3+Bb^3}{Aa+Bb} \right)^{1/2} \quad \text{etc}$$

The fraction are the coeff. of
transmission & corresponding
to different geomet. distrib. of body

According to usual formula
the coeff. is a constant.

$$t = Aa \quad (Aa = a^2)$$

Deducing original every
corresponding to A_0 by our formula
we have $(A_0)^2$

$$\text{for } B_0 = \frac{(A_0 + 12)^2}{A_0^2 + B_0^2}$$

$$\frac{4}{2} + \frac{36 \cdot 4}{8 \cdot 4} = 10$$

$$A + B = \frac{(A_0)^2}{A_0^2} + \frac{(12)^2}{B_0^2}$$

Supposing coeff to be constant for
these two rays we would have

$$A + B = \frac{(A_0 + 12)^2}{A_0^2 + B_0^2}$$

$$\frac{(A + 12)^2}{A + 28} = \frac{4 \cdot 16}{2 \cdot 2} = \frac{64}{2} = 32$$

wh. is less than $1 \frac{1}{2}$ or 1.5

In same way if we consider
the original radiation to be
composed of any number of parts
having different coeffs before
absorption.

ultra-violet lines, narrow blocks
cold lines whose absorption
is complete. The rays
nearly extinct, esp. of luminous
very small indeed. Even
on top of Mountaine there
lines appear so that a great
number of these rays have
been extinguished long before
reach man. (This is shown
by photograph) - The
absorption due to these
lines alone is much
greater than usually supposed -
for results obtained are
means of average of

hundreds of changes in rate
of absorption and what
he has shown, too small.
Even when bolometer is used
(area $\frac{1}{2}$ mm) covers at least
a dozen alterations between
brightness and almost total
extinction so that although
we measure approx. homo-
gene lengths, yet in respect
to local or selective absorption
we do not, and our results
too small

To show clearly error in
usual method - Total
radiation divided into 10
parts and the transmission
of each part determined
separately as in table II

Certain rays almost entirely
absorbed (or coef. $\approx .01$), while
others like certain infra
red almost all transmitted
coef. nearly ≈ 1 .

Pregrind tubes unknown	Alb. ind after 1 obs.	After read	after 3	after 4
AlB.C it	Ala, Bl.	Ala ² , Bl ²		
1	.01	.0001	.000	.0001
1	.1	.01	.007	.0001
1	.2	.04	.008	.0016
1	.6	.36	.216	.12 96
1	.7	.49	.343	.2307
1	.7	.49	.343	.2307
1	.8	.64	.512	.4096
1	.9	.81	.729	.6561
1	.9	.81	.729	.6561
1	1.0	1.00	1.000	1.0000
10.	5.9	4.65	3.881	3.31143
Al+B+ = .8	Ala, Bl	Ala ² +Bl ² = 12	Ala ³ +Bl ³ = 0	Ala ⁴ +Bl ⁴ = 18

Coef. of trans. from $\underline{II}$ to $\underline{III} = \frac{N}{NII} = .789$

$$.. .. . 11 + 14 \left(\frac{O}{n} \right)^{1/2} = .812$$

$$.. .. . 11 + 14 \left(\frac{P}{O} \right)^{1/2} = .825$$

And the corresponding
mean absorptions are

$$1 - \frac{K}{NII} = 0.21$$

$$1 - \left(\frac{O}{n} \right)^{1/2} = 0.188$$

$$1 - \left(\frac{P}{O} \right)^{1/2} = 0.175$$

Ok agree well for diff. altitudes

By this method

$$a + \beta - \beta = \frac{(a + \beta L)^2}{a^2 + \beta L^2} = \frac{(5.4)^2}{4165} = 7.5$$

instead of its true value 10.

Ok value we would

obtain by letting β account

of diff. says -

$$A+B+C = \frac{(Aa)^2}{Aa^2} + \frac{(Bb)^2}{Bb^2} + \text{etc}$$
$$= \frac{.07}{.0001} + \frac{.11}{.01} + \frac{.12}{.04} + \text{etc}$$
$$= 10$$

Thus what value we
have giving about 20%
for absorption, yet true
value is

$$1 - \frac{3.9}{10} = 41\%$$

That is value of absorption
may exceed double
the amount derived
from formula

Langley believes that
shortening amounts to
over 40%. From
dewpoints taken at low
elevations and on tops of
mountains as Whistler,

If we admit that
solar heat when absorbed
is not retained in atoms -
(wh. would heat & red hot).
it must be diffused
away from and lowered
up, so that heat
lost by reflection

absorption. we ought
to find either reflection
or diffusion to us from
the sky or turned away
from us.

Highly engaged on
measuring light & heat
that comes from sky men
the sun (still incomplete)
Thoughtfully reflecting we
may say, that we receive
on the average at the
sea level, as much

light from the sky as from
the sun; getting more
from sun at noon; but
more from sky in morning
and evening -

All his investigations
whether at sea-level or
at 15,000 ft alt. seem
to show that absorption
is double that wh. is
usually given

Invisible Heat Spectra

and wave lengths.

"What are wave lengths
of heat from non-
luminous sources, such
as the soil of this planet?"

Spectrum formed by ice
and other cold bodies.

A surface of ice would
be capable of radiating
heat to a colder body &
thus giving a spectrum
Describes actual formation
of such spectra and
approx. measurement
of their wave lengths

Extreme range of normal
eye is about

$$0.00036 \text{ mm} = 0.36 \mu$$

$$\text{to } 0.00081 \text{ " } = 0.81 \mu$$

is a little more than
the octopus.

Fig I shows the normal
spectrum.

at 0.16 μ shortest visible wave

0.29 " color wave that
penetrates skin -

0.35 " visible ray -

.61 longest "

2.7 observed color wave
by Helmholtz -

This fig. shows what
a small part of

spectrum the result is
to find whether the limit
of solar waves 2.7 was
also limit of waves
radiated from terrestrial
sources.

Used bolometer and
rock salt prisms and
lenses.

As radiating surfaces
Leslie cubes were
used. Covered with
lampblack and filled
with boiling water (100°C).

a aniline (170°C)

and also curves filled
with freezing mixtures
~~so that~~ when temp of
surroundings was -2° ,
center at $t = 20$ so that
determining the distribution
of ^{energy} ~~heat~~ in spectrum of
a surface below the
freezing μ of water



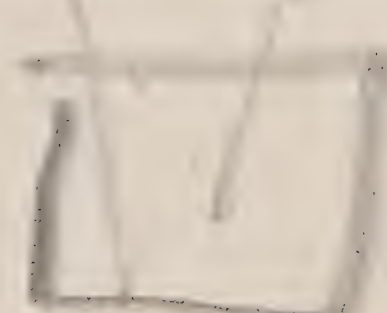
Prime

Upper vessel
filled with
ice

Flange
rod

Thin
screen
rod

Part food
screen



cube

March 20, '81 length of
 cube 175°C . of room -7°C
 excess of temp of cube 182°

Deviation	deflection
-----------	------------

40° 30'

12

40

72

39 30

214

39

364

38 30

420

38

365-

37 30

269

196

37

137

36 30

96

33

10.5-

By repeating the survey
 was found ab 65

be

38 40

420

38 30

428

approx at 38° 71-

Plate III gives curves
showing approx. distribution

of energy in spectrum
when entered at...

170° 100° 50° - 20°

The radiometer was enlarged
so we need only its
approx pos. of sun.
arranged to reproduce
index of position

Deviation of eye. The
mouth were distinctly
protrusible. The last core
the largest - 12 divisions

(1) This part represents
a thin curved as
down at bottom of
different character than
that observed in some.
Glass to examine lenses
some rays but not others

As lens when rises
the max. ordinate
moves towards the

more expansion the end
(could)

The greater portion
of the areas of this
curve lies below the
mean ordinates.

The whole heart of
Spence's proof that
pressure at any point is
that of the body of fluid
in contact with it.

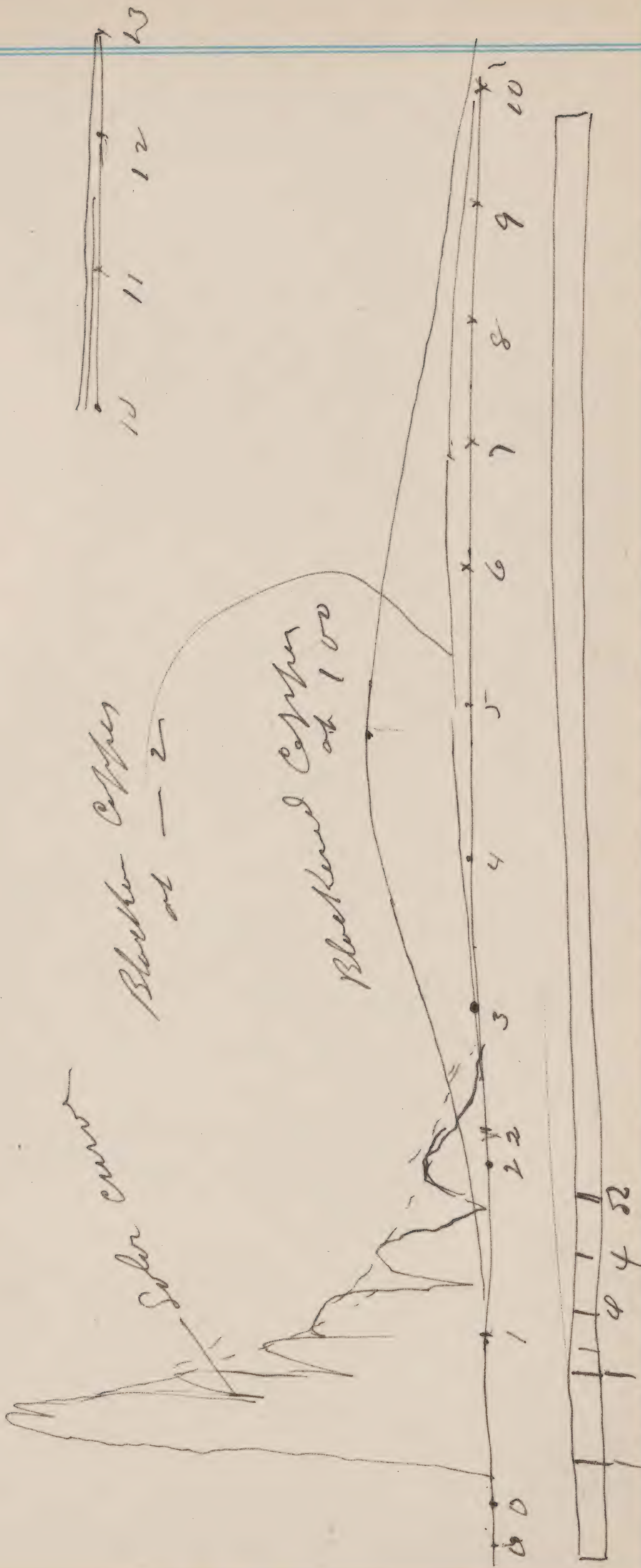
Calculation from
of the by Willmott
New formula

$$R^2 - 1 = -P^2 + Q \frac{\lambda^4}{\lambda^2 - \lambda_m^2}$$

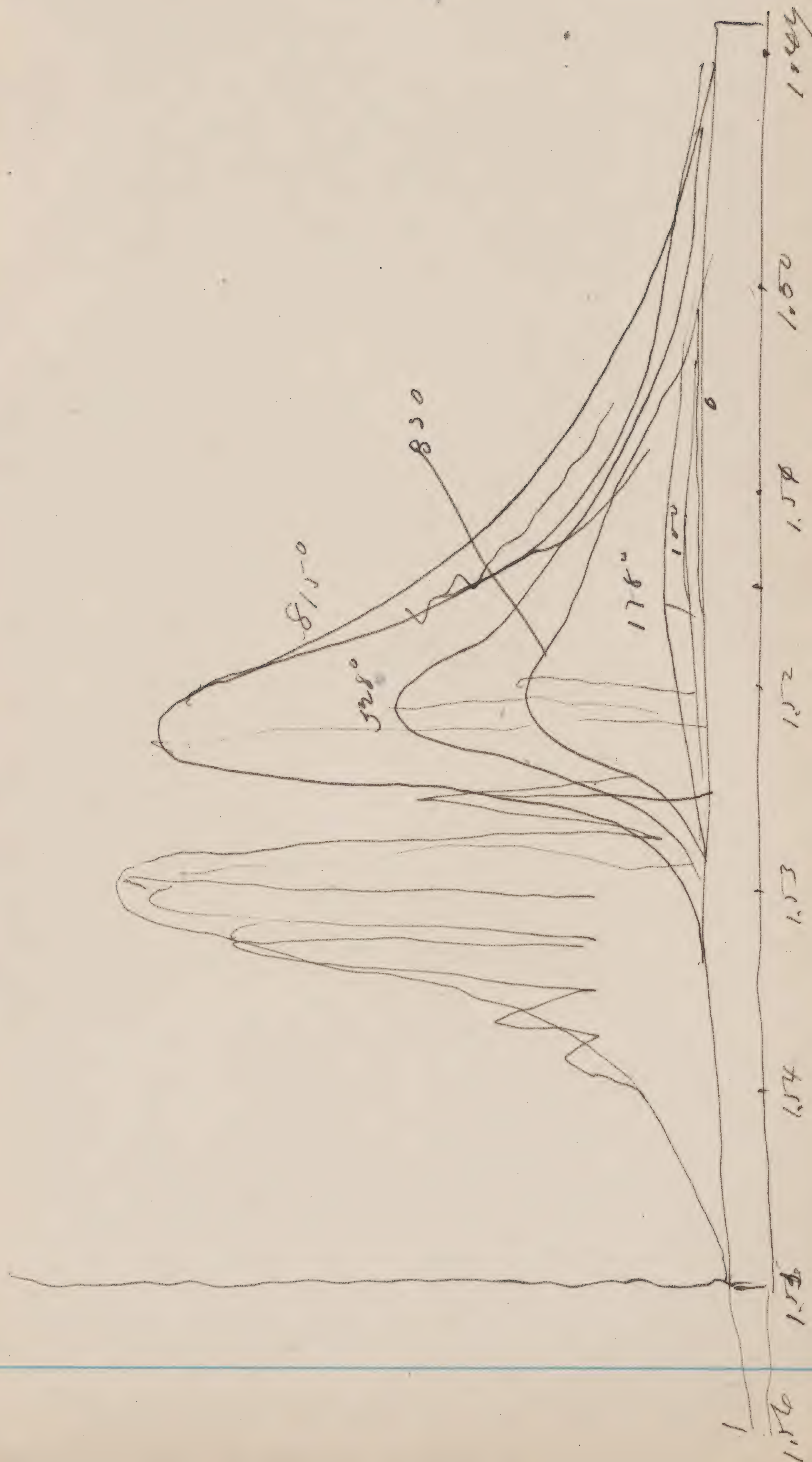
P, Q, λ_m are constants
depending on previous
wave lengths given
in this plate. Considered
as first appears -

Some of heat
radiated from soil
has wave length
probably of over
20 times that of land
with Fraunhofer line

Plate 1



inside



$$x + iy$$

$$r e^{i\theta}$$

$$r(\cos\theta + i\sin\theta)$$

Nov. 1

How to find the sum of all the
factor divisions of n .

The sum of all the powers of a

$$n \quad \frac{a^{\alpha+1}-1}{a-1} \quad \text{of } b \quad \frac{b^{\beta+1}-1}{b-1}$$

take the same of them -

Take for a special case -

$$60 = 2^2 \cdot 3 \cdot 5$$

$$\begin{array}{l} \text{powers.} \\ 1, 2, 2^2 \\ 1, 3 \\ 1, 5 \end{array}$$

There are twelve divisors.

they are, 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, 60

thus sum = 168.

$$\frac{2^3-1}{2-1} = 1 + \frac{2}{2} + \frac{4}{4} = 168$$

If you can break numbers up into
prime factors we may easily find
the G.C. & L.C.M.

The prime totient: This is
the number of numbers not
greater than it, wh. are relatively
prime to it. Number one
is considered relatively prime
to every number and relatively
prime to itself - but every other
number the unit is not
considered relatively prime to
itself.

Prime totient is written $\phi(n)$.

$$\phi(1) = 1$$

$$\phi(4) = 2$$

$$\phi(2) = 1$$

$$\phi(3) = 2$$

$$\phi(3) = 2$$

$$\phi(6) = 2$$

$$\phi(60) = 16$$

1, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 49, 53, 59

$$\phi(59) = 58$$

Let $m = a^{\alpha} b^{\beta} c^{\gamma} \dots$

The numbers prime to m do not contain a, b, c , etc. We wish then to find number of numbers less than m that do contain a - there are

$a, 2a, 3a, \dots, \left(\frac{m}{a}\right)a$.

the number of these are $\therefore \frac{m}{a}$

$\therefore m - \frac{m}{a} = m\left(1 - \frac{1}{a}\right)$ numbers wh. do

not contain a -

Again

$b, 2b, 3b, \dots, \left(\frac{m}{b}\right)b$ (2)

~~the~~ any one And the numbers of numbers in this series that are divisible by a are $\frac{m}{ab}$

$\therefore \frac{1}{a} \left(\frac{m}{b}\right)$, the rest of numbers wh. are not divisible by b are

$$\frac{m}{b} - \frac{m}{ab} = \frac{m}{b} \left(1 - \frac{1}{a}\right)$$

The ~~not~~ left are

$$m \left(1 - \frac{1}{a}\right) \left(1 - \frac{1}{b}\right) \text{ etc.}$$

line of flow: has direction of resultant

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$$

velocity at that point.

Stream lines you follow the particle

$$\dot{x} = u, \dot{y} = v, \dot{z} = w$$

$$\dot{x} = \frac{dx}{dt}$$

Eg. of line of flow in a plane

$$\left\{ \begin{array}{l} \frac{dx}{u} = \frac{dy}{v} \\ u dy - v dx = 0 \end{array} \right.$$

$\frac{du}{dx} + \frac{dv}{dy} = 0$, shows that fluid is incompressible, and also that 1st expr. is an exact differ.

$$u dy - v dx = d\psi$$

$$u = \frac{d\psi}{dy}, \quad v = -\frac{d\psi}{dx}$$

If motion is all in plane passing
thru' axis of z .

Eq. of line of flow

 $\omega(\omega dr - u dz) = 0$

Eq. of continuity.

$$\frac{d}{dr} \omega u + u \frac{d\omega}{dz} = 0$$

and

$$\omega = \frac{1}{r\omega} \cdot \frac{d\psi}{dr}, \quad u = -\frac{1}{r\omega} \frac{d\psi}{dz}$$

Velocity potential ψ . polar coord.

$$\frac{d^2\psi}{dr^2} + \frac{2}{r} \frac{d\psi}{dr} + \frac{1}{r^2} \frac{d^2\psi}{d\theta^2} + \frac{\omega^2}{r^2} \frac{d\psi}{d\theta} = 0$$

$$+ \frac{1}{r^2 \sin^2\theta} \frac{d^2\psi}{d\phi^2} = 0$$

Cylindrical coord.

$$\frac{d^2\psi}{dr^2} + \frac{1}{r} \frac{d\psi}{dr} + \frac{1}{r^2} \frac{d^2\psi}{d\theta^2} + \frac{d^2\psi}{dz^2} = 0$$

If there is a motion in fluid
symmetrical to a point, velocity
is independent of angle
of position of the point

hence we have

$$\frac{d^2 \phi}{dr^2} + \frac{2}{r} \frac{d\phi}{dr} = 0 \quad \text{Laplace's equation}$$

$$\frac{d\phi}{dr} = \frac{m}{r^2} \quad \text{or} \quad \phi = -\frac{m}{r}$$

If m is positive the ϕ is from a source and all lines diverge from it. - m negative all converge and ϕ is called a sink.

If the two charges are equal they are called a doublet. Inside electric field of ϕ is + elect. a source, if -, a sink



for a doublet consists of an infinitely small magnitude.

As if you had an infinitely small vortex ring.

Flux across any closed surface -

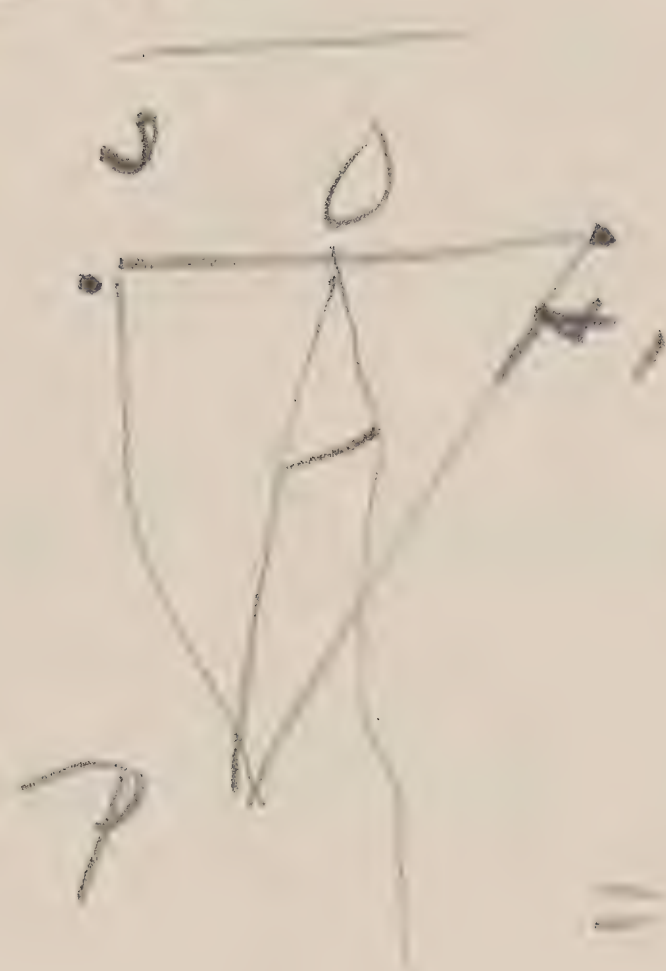
$$\iint \frac{d\mathbf{f}}{r^2} dS = \iint \frac{m}{r^2} \cos \theta dS$$

(Solid angle etc in sphere etc)



$$= m \iint d\Omega = 4\pi m$$

But for a source, or a sink



S = source
H = sink

$$\phi = -\frac{m}{SP} + \frac{m}{HP}$$

$$= -\frac{m SH \cos \theta}{r^3}$$

$$m SH = \mu$$

$$\phi = -\frac{\mu \cos \theta}{r^2} = -\frac{\mu z}{r^3}$$

= " a given amount of power - z

$$= -m \frac{z P_1}{r^3} = -\mu \frac{P_1}{r^2}, \quad \text{potential}$$

due to a magnet -

$$\phi = - \iint \frac{m}{r^2} \cos \epsilon dS = - \int m d\Omega$$

$\phi = - m\Omega$. Case of
a magnet shell -

History of Thermodynamics -

Holzmann 1845. Phys. Ann. vol. 72

First to give Carnot function
in the form $\frac{I}{a+b}$.

~~Rankine~~

Jas. Thomson - Trans. of Edinb.

Jan. 49. showed that freezing

pt of water lowered by pressure -

Rankine - hypothesis of molecular

voids - As consequence of

his general equation Carnot's

second law follows - Must come

in with hypothesis

Elasticity due to heat arises from
centrifugal force -

1853-4 - deduced from his hypo-
gave name to Thermodynamic
function (Entropy)

Finds a general expression
for specific heat of gases.

Adiabatic expansion means
condensation in case of steam -

1857, 21st April - Deduced Law
of efficiency of perfect heat
engine $\frac{W}{H} = \frac{T_1 - T_0}{T_1 - K}$

T_1 absolute energy of sources -
deduced from his fundamental
equation - K very small

1830 Clausius. - Month & April -
Wiedemann's Annalen -
Specific heat of sub. vapor
is negative -

Rapin & Thomson used expression

$$L = C(S - \sigma) \frac{dp}{dt} \quad \text{to calculate}$$

C₁ - Carnot's function -
Clausius form

$$C = \frac{\alpha + t_0}{T}$$

See also Thomson's most
important paper on subject -
March. 1851 -

Reviews thermodynamics etc -

Found in Phil. Mag. 1845 -

May

Part 5th of Thomson's paper - on
electric energy.

6th May 54. Thermoelectric
Current - and second scale
of temperature

7th Part. in two collected reports
Thermoelectric, & the generation of matter
' magnet

1852 Proc. Roy. Soc. E. with
worked in non-reversible engine.
 $W = \frac{1}{2} \int_0^{\infty} \frac{1}{\gamma} \text{ and } \text{etc}$

1870 - Capillary surface etc -

1854 Roy. Am. Soc. Clausius.

Law of equiv. of transformations

1856 Roy. Am. - Mechanical theory
of heat & steam engine

1859 Rankine book on steam
engine -

1867 Pogg. An. p. 116 Clausius -

Internal work - Chemical
actions may be treated from
stand. of mechanical eqvt -

1858 Pogg. An. Kirchhoff. vapor
tension ~~greater~~ less over ice than
over water - Another paper
in same vol. - A law for
intrinsic energy -

Absorption of gas in water -

Hellm. Goltz paper Vol II

Trans. Conn. Acad. of S.

Strahlung.

Phil. Trans 1884 -

Miller

Radiation of heat - Stewart
and Kirchhoff - Prevost's law
of exchange.

• Newton & Fourier, laws.

Leslie, Rumford, Pictet & Prevost.

Fourier, Journal de Physique 1791

Before then all bodies hot
or cold radiate bodies. A

number of bodies in an enclosure
exposed to heat will ulti-
mately arrive at same temp.

Stewart. 1858-

- (1) - Compared heat radiation
from polished surface with
from that from lamp black
- (2) Compared quality of heat
radiated from polished surfaces
with that from lamp black
- (3) Plates of same substance
but diff. thickness.

The heat conducted by rock
salt, glass, mica is
less transmissible than

11111111 / Lamp Glass
11111111 / rock salt
11111111 / Lamp Glass

Radiation from a chattering
body: less radiation and it
increases with thickness.

Radiation

Substances wh. radiate heat
are opaque for heat radiated
by themselves - Absorption
= Radiation -

Two laws measuring
the flow of heat from the
surface of a substance upon
surface of radiation

Thickness as proper to the
square of radius of sphere

3^d Paper.

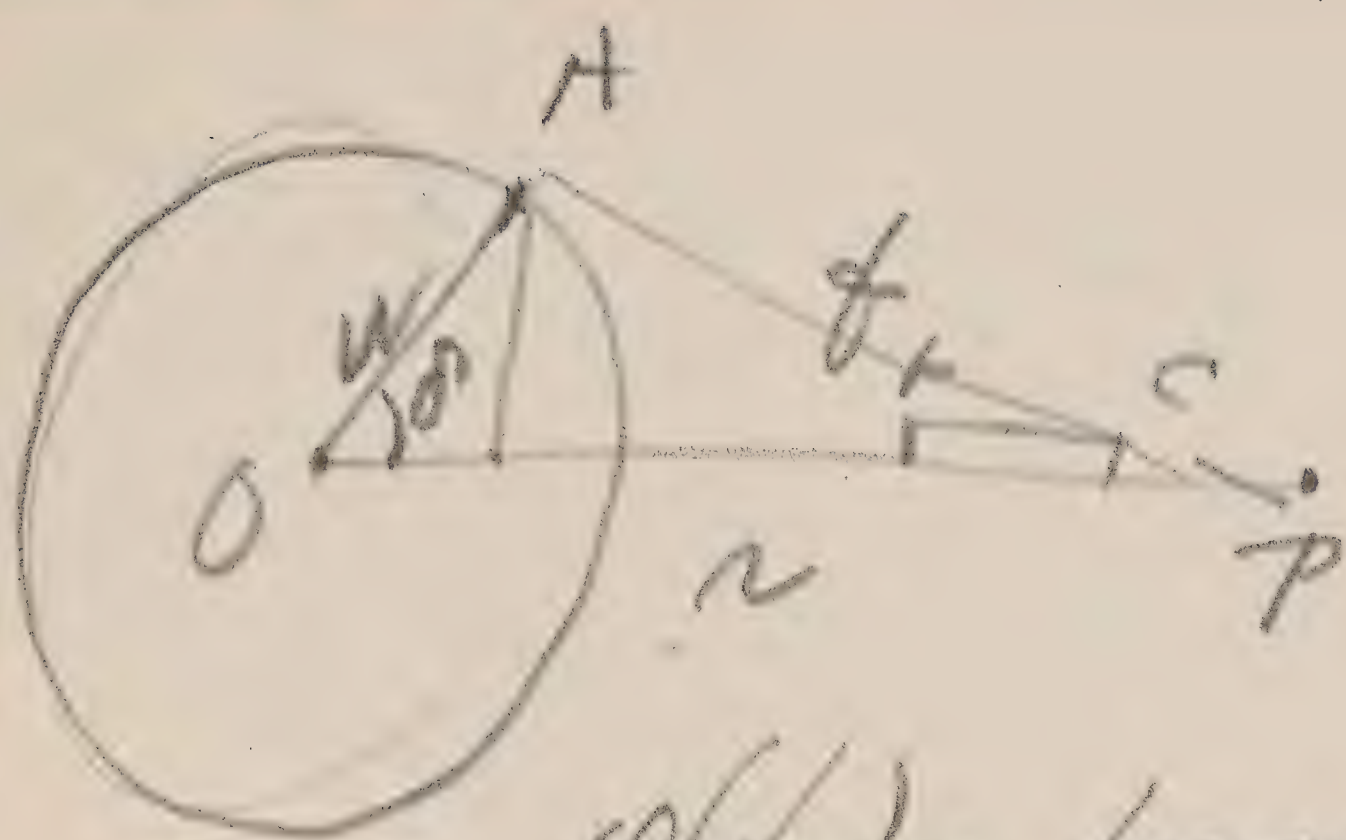
Phil. Mag. vol. 50 series 44

Capillary action
Lomax.

Phil. Tran 1711

Young 1st correct explanation

Laplace - density of liquid
is constant and attractions
are insensible at sensible
distances -



$\phi(f)$ = force between two particles at distance f , repulsive at inc. distance & vice versa at dec. dis -

$$\phi(f) \int u^2 du \sin \delta d\delta d\omega \phi(f) \frac{u - u \cos \delta}{f}$$

$$f^2 = u^2 + r^2 - 2ur \cos \delta$$

$$f df = r dr - u \cos \delta d\delta$$

$$\frac{df}{dr}$$

substit.

$$\frac{d}{dr} \left(\int u^2 du \sin \delta d\delta d\omega \int \phi(f) \frac{u - u \cos \delta}{f} \right)$$

= attraction of A on P -

integrating over sphere

$$- \frac{d}{dr} \left(2\pi r^2 du \sin \delta d\delta \pi(f) \right)$$

$$\sin \delta d\delta = \frac{\delta}{ru} df$$

$$\int_0^{\delta} \pi(f) df = Q(f)$$

$$- \frac{d}{dr} \left(2\pi \int_0^{\delta} \frac{u du}{r} [Q(r-u) - Q(r+u)] \right)$$

$$\frac{2\pi u du}{r} [Q(b-u) - Q(b+u)]$$

$$- \frac{2\pi u du}{r} [Q(c-u) - Q(c+u)]$$

$b+u = \text{resistible}$

$c-u = \text{"}$

$\therefore c+u = \text{"}$

$\therefore$ drop this

and attraction is

$$\frac{2\pi r dr}{r} \phi(b-u)$$

$$b-u = z$$

$$\int_0^b \frac{2\pi(b-z) dz}{b} \phi(z)$$

the attraction of the sphere
on a little column of liquid
bounding the sphere

Let

$$K = 2\pi \int_0^b \phi(z) dz$$

$$H = 2\pi \int_0^b z \phi(z) dz$$

$$K = \frac{H}{b}$$

and also a pressure on unit
area at rt. angles to the column
the sphere

